PROTECTION CONFIGURATION SCHEME AND APPLICATION IN DIGITAL SUBSTATION

Chun-he ZHANG
China
zhangch@nari-relays.com
NR Electric Co., Ltd. China

Zhengjun LU
China
luzhj@nari-relays.com
NR Electric Co., Ltd. China

Jiuhu LI
China
lijh@nari-relays.com
NR Electric Co., Ltd. China

Wei YAN
China
yanw@nari-relays.com
NR Electric Co., Ltd. China

ABSTRACT

Two protection configuration schemes in digital substation automation system are introduced, analyzed and compared on reliability, cost, etc. Applications of over-current protection with reverse blocking for busbar and automatic bus transfer equipment based on IEC61850 is described.

0 INTRODUCTION

Over recent years, with the development of technologies related to sensor and transducer, power electronics, and communication, substation automation is facing more challenges and tasks, for example, primary and second equipment integration (intelligent primary equipment), system integration and condition monitoring.

In china, there are thousands of substations in operation while hundreds of substations of different voltage levels are built every year. In these substations, different types of substation automation systems are in use. It is very important to simplify configuration and reduce costs for substation automation systems. So, this paper takes a 110kV substation as an example, studies and discusses these problems. In the paper, two feasible protection configuration schemes are proposed as well as method to realize 10kV busbar protection, and automatic busbar transfer.

1. SCHEME 1

The main circuit diagram of one 110kV substation is shown in Fig.1. Two power transformers may or may not operate in parallel and every power transformer connects two 10kV bus sections. A schematic of process level and bay level is also shown.

In this substation, dual sampling configuration is adopted at both sides of 110kV power transformer, namely conventional CT and PT, and electronic instrument transformer. Sampled measuring value (SMV) network at process level realizes data acquisition for bay level from merging units. Sampled value message adopts IEC61850-9-2 standard. There are two physically independent SMV networks at 110kV voltage level, and single SMV network at 10kV voltage level.

1.1 Bay level protections

(1)Transformer main protection and control

Duplicated protection and control equipments with digital interface provide transformer differential protection, backup protection, measuring and control functions. In order to eliminate dependency of transformer protection on 10kV side process level network switch, transformer LV side GOOSE and SMV data are directly acquired from the unified equipment-transformer LV side intelligent measuring, control and merging unit. Local intelligent terminal unit is equipped at transformer HV side.

(2)Transformer auxiliary protection and control

A transformer auxiliary intelligent terminal unit provides mechanical protection, neutral point earthing switch control, and on-load tap changer control function. Signals, such as on-load tap position, neutral point earthing switch, and transformer mechanical quantities etc. are connected to this intelligent terminal via copper wiring cables.

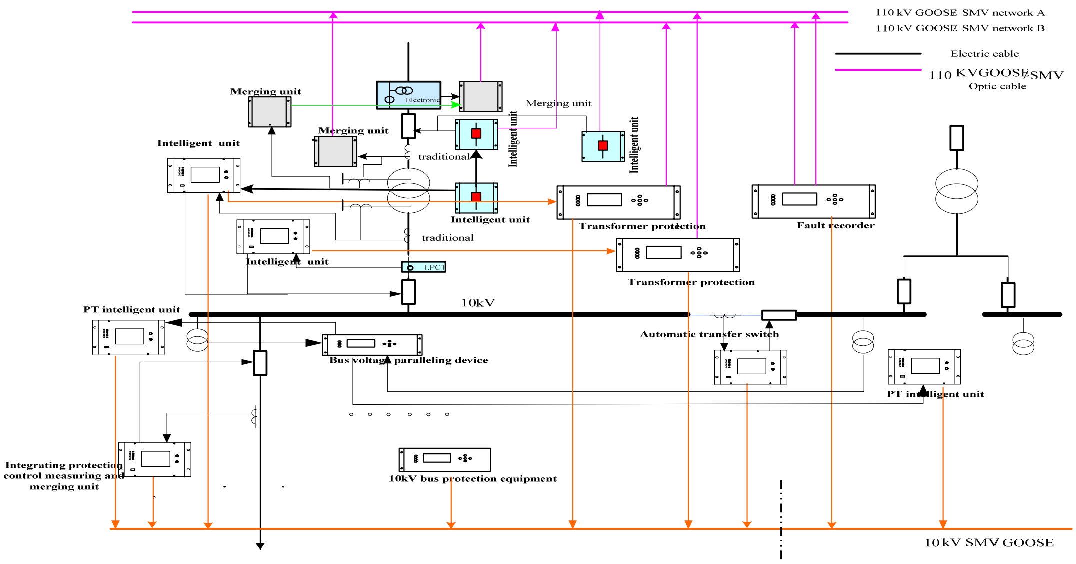

Fig.1 Scheme 1

This terminal unit is equipped locally and connected to station level network to upload or receive GOOSE commands.

(3) Unified terminal unit for 10kV transformer LV side
Unified terminal unit with measuring, control and SMV merging functions fully supports IEC61850 standard and is bay-oriented. Currents for protection and measurement are taken from electronic instrument transformer, voltages are taken from conventional instrument transformers, neutral point current is taken from conventional instrument transformer, and sampled value digital signals are output via IEC 61850-9-2 interface. Duplicated intelligent terminal units are installed locally on the 10kV control panel.

(4) 10kV bus protection equipment
Two sets of bus differential protection are equipped, one for each transformer. They are distributed bus differential protection with digital interface specially designed for DSAS. GOOSE message is used to send trip signal and IEC61850 standard is supported. Sampled values of each bay for bus differential protection are acquired from SMV network. The trip command sent by GOOSE message will be executed by intelligent auxiliary relay.

(5) Measuring, control, and protection for 10kV substation transformer, feeder, capacitor, and bus section equipment that integrates measuring, control, protection, and merging function is bay-oriented and IEC61850 standard is fully supported. In addition to conventional protections, GOOSE output for reverse blocking bus protection is also provided. The equipment is installed on 10kV control panel.

(6) 10kV bus section transfer device
Sectioned bus transfer device with digital interface is adopted to provide sectioned bus transfer function, loads distribution, and overload intertrip function.

1.2 Summary of configuration

It can be seen from above configuration that:
(1) For a 110kV substation, equipment that unifies bay level functions and process level functions has emerged. 10kV feeder line etc. adopts equipment that integrates measuring, control, protection, and merging function.

(2) 10kV busbar is equipped with 2 sets of busbar protection, one is a complete differential protection function and another is reverse blocking protection function respectively.

(3) Due to reliability, 10kV feeder etc. do not adopt iron core coil type low power current transformer (LPCT).

(4) As pilot DSAS, there are many dual configurations, and redundant equipments at process level and bay level, so that configuration is complicated and costs are high.

2. SCHEME 2

With development of technologies, in particular gradual maturing of digital technology, there are reasons to believe that protection configuration of future 110kV substations will become simple and reliable, and cheaper.
Single Sampling configuration at process level of both sides of transformer will be adopted. Only electronic instrument transformers (except for neutral point CT) are configured.

2.1 Bay level protection

(1) Transformer backup protection will be distributed. Sub-unit backup protections will be arranged according to voltage levels. Direct sampling, local measurement, and local control will be adopted.
At 110kV side, for indoor GIS station, protection control

and measuring intelligent unit of 110kV side will be installed locally in GIS local control panel; for outdoor station, this will be locally installed in the intelligent control panel [3] .At 10kV side, the intelligent equipment integrating protection, control, and merging unit is installed in control panel. This mode realizes localized protections, greatly improving protection reliability.

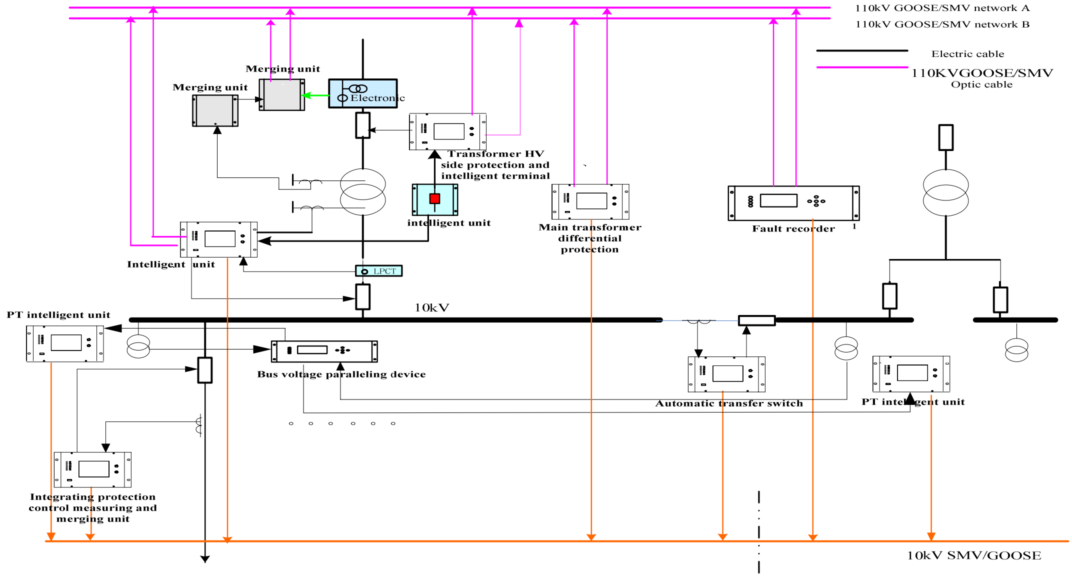

Fig.2 Schematic of process level and bay level in the 110kV digital substatio

(2) Transformer differential protection can receive data sent by sub-units at both sides via fiber optic channel. Tripping of bus coupler and bus sectionalizer, blocking of automatic bus transfer, and initiating of breaker failure etc. will be transmitted on GOOSE network. Transformer protection can use GOOSE network to receive breaker failure protection tripping commands and trip circuit breakers at all sides.

(3) 10kV busbar protection equipment
One set of reverse blocking protection is applied.

(4) 10kV bus section protection equipment
This protection includes bus transfer and protection functions.
Configuration of other protections is the same as that for scheme 1.

2.2 Summary of configuration

(1) If digital substation automation system is expected to be widely used at 110kV voltage level, great cost reduction is a must. This scheme is the best choice to this end. Naturally, if cost is not the key, backup protection intelligent units at transformer LV side and HV side can be duplicated.

(2) Direct acquisition and tripping of protection improves reliability. In case of fault in differential protection fiber optic channel, backup protection and local tripping still function.

3. REALIZATION OF REVERSE BLOCKING PROTECTION FOR 10KV BUSBAR

3.1 Principle of busbar reverse blocking protection

Busbar reverse blocking protection is not an independent protection. It consists of operating elements embedded in transformer backup protection equipment or bus coupler (sectionalizer) and blocking elements embedded in protection devices such as bus coupler (sectionalizer) and feeders etc. As busbar reverse blocking protection requires transmission of startup and blocking signals among a number of devices, in traditional mode, much binary input hard wiring exists between each feeder protection/sectioned protection and the busbar reverse blocking protection, resulting in complicated secondary circuits, vulnerability to errors, low reliability, and poor realtime property.
GOOSE communication mechanism has been well verified even in some substations that adopt traditional sampling. The advantage of GOOSE is that once physical connection is established, as long as channel bandwidth is sufficient, connections can be added at will with high expandability. By means of GOOSE communication, incorrect closing of conventional contacts is completely avoided, and in case that GOOSE network link is interrupted, alarm signal can be generated immediately.

3.2 Scheme to realize busbar reverse blocking protection

(1) Block of busbar reverse blocking protection
In case of fault in feeder, an output from feeder protection will block corresponding transformer LV side and bus coupler (sectionalizer) busbar overcurrent protection; In

case of breaker failure, the blocking signal will be released then after.
This function is configured in feeder, station transformer and bus section protection.

(2) Busbar reverse blocking protection
This is in fact an overcurrent protection with reverse blocking function.
In case of switch failure and dead zone fault, after busbar reverse blocking protection trips LV side breaker, if fault current remains, upper level breaker will be tripped after a time delay.

3.3 Handling of DG feeders

For feeder that connect to disperse generations (DG), the protection of that will always issue a blocking signal whenever a fault happens on busbar or feeders.
The overcurrent element of busbar reverse blocking protection will trip these feeders first.

4. AUTOMATIC BUS TRANSFER

In main circuit diagram shown in Fig.1, information required for automatic bus transfer comes from 3 bays (LV side of 2 transformers and sectionalizer). For traditional bus transfer device, analog inputs, binary inputs and binary outputs are connected via copper wiring cables. With the development of digital substation automation system, traditional secondary copper wiring cables are replaced by communication network, and all equipments at process level and bay level can share information and transmit configuration and control commands via this network.
All binary inputs and outputs of digital automatic bus transfer device are based on GOOSE. However, sampled values transmission mode varies:
(1) AC quantities are obtained from electronic instrument transformers via multimode fiber channel and merging unit. Fiber optic communication follows IEC60044-8 standard protocol. The following analog quantities are transmitted by PTP optic fiber: three phase current and zero sequence current of bus section, one phase current and line voltage of the two power supplies, and three phase voltages of two busbars.
(2) All AC quantities can be transmitted based on IEC61850-9-2 sampled values transmission protocol. In the scheme of Fig.1, SMV and GOOSE share a common single network.
Digital automatic bus transfer will be executed by corresponding intelligent unit of the target breakers. This is different from conventional automatic bus transfer.
Overload intertrip can also be provided by automatic bus transfer device. All the load shedding commands are output via GOOSE.

5. CONCLUSION

Two protection configuration schemes for 110kV digital substation automation system are proposed. The first scheme is highly redundant and feasible in the early stage of digital technology development. The second scheme is simple and cost-saving, provided that technologies are mature and reliability is concerned.
Over-current protection with reverse blocking for busbar and automatic bus transfer introduced in the paper can increase the reliability for substation with less cost.
Most of these products have been applied in real projects and are now running well.

Reference

[1] Li Gao, Application of Digital Substation to Sichuan Power Network, SICHUAN ELECTRIC POWER TECHNOLOGY , 31(3) 28-31